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National Hydrology Research Institute
Institut national de recherche en hydrologie

Inland Waters Directorate
Saskatoon, Saskatchewan, Canada
Direction générale des eaux intérieures
Saskatoon, Saskatchewan, Canada

Canada

92-07056/

ISSN 0838-1992

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FLOATING ICE IN CANADA REFERENCES (1988-1990) AND RECENT WORK

NHRI Contribution No.90052

August, 1990

MANAGEMENT PERSPECTIVE

The establishment of a national or international focus for hydrology at the National Hydrology Research Institute means that staff there accept positions with national and international bodies. One appropriate activity is that of Canadian national correspondent for one of the commissions of the International Association of Hydrological Sciences. Simon Ommanney is the National Correspondent for the International Commission on Snow and Ice. One of his roles is to prepare an annual report on snow and ice research in Canada for publication in the Canadian Geophysical Bulletin. This report contains a bibliography and other background information for the 1989 report (CS-90054).

PERSPECTIVE DE GESTION

L'établissement à l'Institut national de recherche en hydrologie d'un groupe national ou international de recherche spécialisée en hydrologie signifie que les employés de l'Institut sont prêts à accepter des postes dans des organismes nationaux ou internationaux. Une activité appropriée est celle du correspondant canadien pour l'une des commissions de l'Association internationale des sciences hydrologiques. Simon Ommanney est le correspondant national pour la Commission internationale de la neige et de la glace. L'un de ses rôles consiste à préparer un rapport annuel sur la recherche en matière de neige et de glace au Canada pour publication dans le Bulletin canadien de géophysique. Le présent rapport contien une bibliographie et des renseignements supplémentaires pour celui de 1989 (CS-90054).

FOREWORD

As Canadian Correspondent to the International Commission on Snow and Ice (ICSI), C.S.L. Ommanney is responsible for preparing annual reports on floating ice investigations in Canada for the Associate Committee on Hydrology and their review of current activities for the Canadian Geophysical Bulletin. This report complements that review. It summarises references to work done in Canada, on Canadian marine and freshwater floating ice, and by Canadian glaciologists; published between 1988 and 1990. The listing includes unpublished reports and newspaper articles. The latter, because of the location of the author and the availability of information, are biased towards Saskatchewan sources. The scientific articles reflect the activity of university, government and private sector scientists in different parts of the country.

As this is only a preliminary listing, readers are asked to advise the compiler of any errors or omissions. Many of the references have not been verified and some of these may not in fact deal with Canadian floating ice or may not be authored by Canadians.

The Appendix contains copies of the data sheets submitted to the ICSI Correspondent from glaciologists across Canada in response to a request from the Associate Committee of Hydrology for input to the Canadian Geophysical Bulletin. These sheets contain information on completed, current and future work together with contact names and numbers.

As background information for the ICSI report, other companion reports have been prepared on Snow (CS-90050), Glaciers (CS-90051) and Permafrost (CS-90053). These are available on request from the National Hydrology Research Institute.

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WUEBBEN, J.L., 1981. Review of environmental and engineering studies concerning effects of extended navigation on the Great Lakes - Saint Lawrence Seaway system. CRREL Final Report No.PC A07/MF A01, Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers, Hanover, New Hampshire, October, 144 pp.

XIE, Y. and D.M. FARMER, 1989. An examination of ice cracking sound and its spatial distribution. EOS, Transactions, American Geophysical Union, 70(43), 24 October, 1155

XIE, Y. and D.M. FARMER, 1989. The sound generated by propagating cracks in sea ice. Fall Meeting late abstracts, EOS, Transactions, American Geophysical Union, 70(20), 16 May, 599

YAO, T. and M. IKEDA, 1988. A model of sea ice and upper ocean mixed layer off Labrador. Contract Report, Bedford Institute of Oceanography, Fisheries and Oceans, Dartmouth, Nova Scotia, 23 March, 52 pp.

YAPA, P.D. and H.T. SHEN, 1988. Unsteady flow simulation for an ice-covered river: closure. Journal of Hydraulic Engineering, 114(3), American Society of Civil Engineers, March, 358

YOUNG, C., 1989. Ecology and conservation of the polar regions. Ambio, 18(1), 23-33

ZWALLY, J., 1988. Analysis of sea ice dynamics. In - Laboratory for Oceans, N89-28118/2, PC A12/MF A01, Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, Maryland, abstract, 4 pp.

ZWALLY, H.J., 1988. Measuring global change in polar regions. Abstracts for the AGU Fall Meeting, EOS, Transactions, American Geophysical Union, 69(44), 1 November, 1045

ZWALLY, H.J., 1988. Polar ice research using passive microwave observations. Abstracts for the AGU Fall Meeting, EOS, Transactions, American Geophysical Union, 69(44), 1 November, 1252

ZWALLY, H.J. and J.E. WALSH, 1988. Seasonal and interannual variations in arctic multiyear sea ice distribution. Abstracts for the AGU Fall Meeting, EOS, Transactions, American Geophysical Union, 69(44), 1 November, 1276

ZWALLY, H.J. and J.E. WALSH, 1990. Seasonal and interannual variations in arctic multiyear sea ice distribution. In - Sea Ice Properties and Processes, Proceedings of the W.F. Weeks Sea Ice Symposium, S.F. Ackley and W.F. Weeks (Editors), CRREL Monograph No.90-1, Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers, Hanover, New Hampshire, abstract, 192

APPENDIX

CURRENT FLOATING ICE RESEARCH

Organization and Address Alberta Research Council, P.O. Box 8330, Station F, Edmonton, Alberta, T6H 5X2	**Tel.No.** 403-450-5279
Department/Branch	**FAX No.** 403-461-2651

Researchers

D. Andres

Project Title **Interstation storage losses during freeze-up on regulated rivers**	**Status** **New** [ ] **Ongoing** [ ] **Completed** [X]

Objectives

A numerical ice-formation model has been developed to simulate freeze-up on a large regulated river to compute the flow lost to channel storage during freeze-up. Final report is due in August, 1989.

Methods

Lab [ ] **Field** [ ] **Modelling** [X] **Others**

Findings

Publications

Organization and Address	Tel.No. (S. Beltaos)
NWRI, Canada Center for Inland Waters, Environment Canada, Burlington, Ontario, L7R 4A6	416-336-4898
Department/Branch Environment Canada	**FAX No.** 416-336-4989

Researchers
Spyros Beltaos (NWRI) and Brian C. Burrell (Hydrotechnical Engineer, Environment Planning & Sciences Branch, New Brunswick)

Project Title	Status	
Restigouche River Ice Project	New	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

To understand how break-up events are initiated and how ice jams develop.

Methods
Lab [ ] **Field** [X] **Modelling** [ ] **Others**

Findings

It is possible to predict the configuration of the jam near the toe using a numerical algorithm that solves appropriate differential equiations.

Publications

Beltaos, S. and B. Burrell, 1990. Case Study of a Grounded Jam: Restigouche R., N.B. Proceedings, Northern Hydrology Symposium, T.D. Prowse and C.S.L. Ommanney (Editors), 10-12 July 1990, Saskatoon, Saskatchewan, NHRI Symposium No.6, in press

Beltaos, S. and B. Burrell, 1990. The Restigouche River Ice Project. Proceedings, 47th Annual Eastern Snow Conference (in preparation).

Organization and Address National Hydrology Research Institute, 11, Innovation Blvd, Saskatoon, Saskatchewan, S7N 3H5	Tel.No. 306-975-5749
Department/Branch Hydrological Sciences Division	FAX No. 306-975-5143

Researchers

H.A.M. Chew and T.D. Prowse

Project Title **Radiation-Ice Modelling**	Status New [ ] Ongoing [X] Completed [ ]

Objectives Develop cold laboratory facility for solar radiation simulation, crystallographic analysis and ice growth. Review radiation attenuation models. Study relationship between radiation and porosity.

Methods
Lab [X] **Field** [X] **Modelling** [X] **Others**

Findings

The AES computer model to predict the change in snow albedo under melt conditions is suitable (with some modification) for Canadian regions.

A solar radiation simulation system has been designed and assembled in the laboratory and facilities now exist for manufacturing columnar ice, for thin sectioning and for cross-polarized crystallography.

Preliminary results show that short-wave radiation at temperatures constantly at or slightly below zero can produce porosity in ice.

Publications

Prowse, T.D., M.N. Demuth and H.A.M. Chew, 1989. The strength and radiation-induced decay of freshwater ice: a review of processes, theories and current NHRI research. Paper prepared for XXIII IAHR Congress, 21-25 August 1989, Ottawa, Ontario [CS-89053]

Prowse, T.D., M.N. Demuth and H.A.M. Chew, 1990. Changes in the flexural strength of ice under radiation decay. Proceedings, 8th Northern Research Basin Symposium and Workshop, **-** March 1990, Abisko, Sweden, Nordic Hydrology *(*), **-** [CS-89087]

Organization and Address New Brunswick	Tel.No. 506-453-4521
Department/Branch Civil Engineering	FAX No. 506-453-3568
Researchers K.S. Davar	
Project Title Integral analysis of river ice cover cracking and breakup - 1990	Status New [ ] Ongoing [X] Completed [ ]
Objectives	
Methods Lab [ ] Field [X] Modelling [ ] Others	
Findings	
Publications	

Organization and Address	Tel.No.
National Hydrology Research Institute, 11, Innovation Blvd, Saskatoon, Saskatchewan, S7N 3H5	306-975-5749
Department/Branch Hydrological Sciences Division	**FAX No.** 306-975-5143

Researchers

M.N. Demuth and T.D. Prowse

Project Title	Status	
Dynamics of Break-Up Advance	New	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

Assess river ice processes associated with the snowmelt-break-up advance period. Select and instrument field site and develop appropriate monitoring.

Methods

Lab [ ] Field [X] Modelling [X] Others

Findings

For the first time heat and mass balance calculations of an ice jam have been made. Conceptual models of processes related to ice sheet failure were compiled and revieved A methodology for determining the failure envelope in compression of decaying columnar ice was established. The borehole jack indentation process was modelled based on simplified circular footing geometry and interaction with a perfectly plastic tresca material. Flexural tests of deteriorating ice at Floral Pond were completed.

Publications

Prowse, T.D., 1988. Field determination of ice jam porosity. Proceedings, 9th International Symposium on Ice, IAHR, K. Saeki and K. Hirayama (Editors), 23-27 August 1988, Sapporo, Japan, Committee on Ice Problems, IAHR, Vol.2, 316-325: Discussion and reply, Vol.3, 275-277; Errata, Vol.3, 318

Prowse, T.D., 1989. Ice break-up on northern rivers: the Liard River as an example. In - Northern Lakes and Rivers, W.C. Mackay (Editor), Occasional Publication No.22, Boreal Institute for Northern Studies, 24-42

Prowse, T.D. and Marsh, P., 1989. Thermal budget of river ice covers during breakup. Canadian Journal of Civil Engineering, 16(1), February, 62-71

Organization and Address CARTEL, Université de Sherbrooke, 2500 boulevard Université, Sherbrooke (Québec), J1K 2R1	Tel.No. 819-821-7181
Department/Branch CARTEL	FAX No. 819-821-7238

Researchers

Jean-Marie Dubois et Pierre Larouche

Project Title	Status	
Courants marins et dérive des blocs de glace	New	[ ]
	Ongoing	[ ]
	Completed	[X]

Objectives

Evaluer la direction et la vitesse des courants marins de surface par télédétection de la dérive des blocs de glace.

Methods

Lab [ ] Field [ ] Modelling [X] Others Images satellitaires

Findings

Il faut tenir compte du stress du vent et de l'eau ainsi que de la force de coriolis. Avec des images MSS, le traitment en mode analogique est presque aussi valable qu'en mode numérique.

Publications

Larouche, P. et J.-M.M. Dubois, 1988. Évaluation dynamique de la circulation de surface utilisant la dérive de blocs de glace (baie d'Hudson, Canada). Photo-Interprétation, n° 88-6, 19-28

Organization and Address	Tel.No.
C-CORE, Memorial University of Newfoundland, St. John's. Newfoundland, A1B 3X5	709-737-8371
Department/Branch Ice Engineering	**FAX No.** 709-737-4706

Researchers

Dat Duthinh and Ken Klein

Project Title	Status
Full Scale Iceberg Impact	New [ ] Ongoing [X] Completed [ ]

Objectives

1. Load caused by impact of an iceberg on a fixed structure.
2. Strength of ice on a large scale.

Methods

Lab [ ] Field [X] Modelling [ ] Others

Findings

A 1700 tonne iceberg was towed at 0.89 m/s into a cliff. The impact lasted 2.25 s, and caused a force of 4.5-6.5 MN over an area 1.8-3.6 m^2 the ice strength is 1.3-3.6 MPa.

Publications

Duthinh, D., J. Newell and A. Steel, 1989. Feasibility study of full scale iceberg impact experiments. Proceedings, 8th International Conference on Offshore Mechanics and Arctic Engineering - 1989, N.K. Sinha, D.S. Sodhi and J.S. Chung (Editors), 19-23 March 1989, The Hague, The Netherlands, American Society of Mechanical Engineers, New York, Vol.4, 383-392

IAHR 1990, Espoo, Finland

Organization and Address Department of Civil Engineering, University of Alberta, Edmonton, Alberta, T6G 2G7	Tel.No. 403-492-2066
Department/Branch Civil Engineering	FAX No. 403-492-0249

Researchers

R. Gerard

Project Title River Ice Processes	Status New [ ] Ongoing [X] Completed [ ]

Objectives

Methods
Lab [ ] Field [ ] Modelling [ ] Others

Findings

Publications

Organization and Address	Tel.No.
Atlantic Geoscience Centre, Bedford Inst. of Oceanography, P.O. Box 1006, Dartmouth, N.S., B2Y 4A2	902-426-9459
Department/Branch Geological Survey of Canada	**FAX No.** 902-426-4104

Researchers

Hequette, A.

Project Title	Status
Beaufort Sea Coastal Zone Geotechnics	New [ ] Ongoing [X] Completed [ ]

Objectives

Project on coastal erosion, wave and current processes, and sea-ice processes.

Methods

Lab [ ] Field [X] Modelling [ ] Others

Findings

Coastal erosion along the Beaufort Sea coast is due to wave-induced processes, thermal-erosion, but also scouring of the nearshore sea floor by sea-ice.

Publications

Hequette, A. and Barnes, P.W., 1990. Coastal retreat and shoreface profile variations in the Canadian Beaufort Sea. In - The Beaufort Sea Coastal Zone, P.R. Hill (Editor), Special Section, Marine Geology, 91(1-2), January, 113-132

Organization and Address Department of Meteorology, McGill University, 805 Sherbrooke Street West, Montréal (Quebec), H3A 2K6	Tel.No. 514-426-2956
Department/Branch Meteorology	FAX No.

Researchers

David M. Holland and Lawrence Mysak

Project Title	Status	
A Coupled Ice-Atmosphere Model for the Arctic	New	[X]
	Ongoing	[ ]
	Completed	[ ]

Objectives

To improve understanding of climate through the ice-atmosphere coupling.

Methods

Lab [ ] **Field** [ ] **Modelling** [X] **Others**

Findings

Project begins June 1990 as a Ph.D. research topic.

Publications

Organization and Address	Tel.No.
Bedford Inst. of Oceanography, Fisheries and Oceans Canada, P.O. Box 1006, Dartmouth, N.S., B2Y 4A2	902-426-3142
Department/Branch Physical and Chemical Sciences	**FAX No.**

Researchers

Motoyoshi Ikeda

Project Title	**Status**	
Sea Ice and ocean circulation on the Labrador Shelf and in the Labrador Sea	**New**	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

Understand sea ice and oceanographic conditions using numerical models and remote sensing data.

Methods

Lab [ ] **Field** [ ] **Modelling** [X] **Others**

Findings

Seasonal advance and retreat of sea ice interannual variability of ice cover and oceanic conditions.

Publications

Organization and Address Department of Geography, University of Waterloo, Waterloo, Ontario, N2L 3G1	Tel.No. 519-885-1211 ext. 2433
Department/Branch Geography	FAX No. 519-888-6768

Researchers

D. Douglas Johnson and Ellsworth F. LeDrew

Project Title High Latitude Atmosphere-Cryosphere-Hydrosphere Climate Interaction	Status	New [ ] Ongoing [X] Completed [ ]

Objectives

To investigate the energy regime of floating ice and open water

Methods

Lab [ ] **Field** [X] **Modelling** [X] **Others**

Findings

Research continuing.

Publications

Barber, B.G., J.M. Piwovar, D.D. Johnson and E.F. LeDrew, 1990. The SIMS project: the study of sea ice as an indicator of climate change and variability. In - Canadian Remote Sensing Contributions to Understanding Global Change, E.F. LeDrew, F. Hedgyi and M. Strome (Editors), Proceedings of the ISPRS Symposium on "Global and Environmental Monitoring", Victoria B.C.

Johnson, D.D., 1990. Satellite remote sensing of polar regions: a review of its development and application to atmosphere-ice-ocean interaction processes. Paper No.ISTS-EOL-TR89-002, Institute for Space and Terrestrial Science, Earth Observations Laboratory, Department of Geography, University of Waterloo, Waterloo, Ontario, April, 76 pp.

Organization and Address Maurice Lamontagne Institute, Min. des Pêches et des Océans, P.O. Box 100, Mont-Joli (Quebec), G5H 3Z4	**Tel.No.** 418-775-6569
Department/Branch Physical Oceanography	**FAX No.** 418-775-6542

Researchers

Pierre Larouche

Project Title **MOS-1 Potential for Ice Reconnaissance**	**Status** **New** [ ] **Ongoing** [X] **Completed** [ ]

Objectives

Evaluate capacity of different sensors on board MOS-1 to determine ice concentrations in marginal ice zones.

Methods

Lab [X] **Field** [ ] **Modelling** [ ] **Others**

Findings

Publications

Organization and Address	Tel.No.
Maurice Lamontagne Institute, Min. des Pêches et des Océans, P.O. Box 100, Mont-Joli (Quebec), G5H 3Z4	418-775-6569
Department/Branch Physical Oceanography	**FAX No.** 418-775-6542

Researchers

Pierre Larouche

Project Title	Status	
Wave Attenuation in a Marginal Ice Zone	**New**	[ ]
	Ongoing	[ ]
	Completed	[X]

Objectives

Evaluate interactions between a wave field and a marginal ice zone.

Methods

Lab [ ] **Field** [X] **Modelling** [ ] **Others**

Findings

Wave attenuation is greatly enhanced when ice is closely packed, because of the energy loss due to the friction between the large number of small floes composing the MIZ.

Publications

Directional wave spectra estimation in a marginal ice zone using linear prediction. Submitted to Journal of Physical Oceanography

Organization and Address	Tel.No.
Science Institute of the N.W.T., Igloolik Research Centre, Igloolik, N.W.T., X0A 0L0	819-934-8836
Department/Branch N/A	**FAX No.** 819-934-8792

Researchers

John MacDonald

Project Title	Status
Growth and decay of sea ice; Turton Bay	**New** [ ] **Ongoing** [X] **Completed** [ ]

Objectives

Determine rates of growth and decay of sea ice, and timing of maximum ice thickness

Methods

Lab [ ] **Field** [X] **Modelling** [ ] **Others**

Findings

First year of study - no results to date.

Publications

- none -

Organization and Address Canada Centre for Remote Sensing, Ice Applications, 2464 Sheffield Road, Ottawa, Ontario, K1A 0Y7	**Tel.No.** 613-952-2739
Department/Branch EMR/SMRSS	**FAX No.** 613-952-7353

Researchers

Michael Manore, Tom Hirose (Noetix Ltd.) and Scott Paterson (Intera-Kenting)

Project Title **Ice Motion Algorithm Development**	**Status** **New** [ ] **Ongoing** [X] **Completed** [ ]

Objectives

Development of automated methods for ice motion mapping from SAR/optical imagery

Methods

Lab [ ] **Field** [ ] **Modelling** [X] **Others**

Findings

Development of algorith (initial) completed. Nov entering test phase using airborne SAR, NOAA-AVHRR data

Publications

Organization and Address National Hydrology Research Institute, 11, Innovation Blvd, Saskatoon, Saskatchewan, S7N 3H5	**Tel.No.** 306-975-5749
Department/Branch Hydrological Sciences Division	**FAX No.** 306-975-5143

Researchers

P. Marsh and L. Lesack

Project Title **Mackenzie Delta Hydrology**	**Status** **New** [ ] **Ongoing** [X] **Completed** [ ]

Objectives Stochastic analysis of long-term water level records for the Delta. Analysis of Beaufort Sea storm surge data to determine the effects on the hydrology of the Mackenzie Delta.

Methods
Lab [ ] **Field** [X] **Modelling** [X] **Others**

Findings

A stochastic analysis of long-term water level records for the Mackenzie Delta has been conducted and a report is in preparation. The initial analysis of Beaufort Sea storm surge data was completed but a report has not yet been prepared. A Mackenzie Delta Workshop was organized and held at NHRI in October, 1989. The proceedings are now in preparation. An analysis of water temperature and heat flux beneath river ice covers has been completed and published. This has demonstrated that it is possible to apply techniques for calculating the heat flux of rough surfaces to the problem of calculating the heat flux to the base of river ice covers.

Publications

Marsh, P. Modelling water temperature in an ice covered river. Canadian Journal of Civil Engineering (submitted)

Marsh, P. and L. Lesack, 1989. Hydrology and environmental impact in the Mackenzie Delta. Abstract, Invited paper to American Society of Limnology and Oceanography Annual Meeting, 18-22 June 1989, Fairbanks, Alaska

Organization and Address Institute of Ocean Sciences, Box 6000, 9860 West Saanich Road, Sidney, B.C., V8L 4B2	**Tel.No.** 604-356-6552
Department/Branch Fisheries & Oceans, Pacific Region	**FAX No.** 604-356-6390

Researchers

Humfrey Melling

Project Title **Ice Subsurface Characterization - Beaufort Sea**	**Status** **New** [X] **Ongoing** [ ] **Completed** [ ]

Objectives

To acquire a regional database for the thickness, draft, underside topography and motion of pack over the continental shelf of the southern Beaufort Sea.

Methods

Lab [ ] **Field** [X] **Modelling** [ ] **Others**

Findings

To date, 3 subsea sonar instruments have been developed and/or evaluated for use in this project. A narrow-beam sonar, in conjunction with precise pressure sensor, is capable of measuring ice draft to within 10 cm on a 2 cm horizontal scale. A four-beam Doppler sonar can measure ice drift rate to within 1 cm/s. A correlation sonar is presently under investigation for ice drift measurement. Preliminary data from the project are under study.

Publications

Organization and Address Institute of Ocean Sciences, Box 6000, 9860 West Saanich Road, Sidney, B.C., V8L 4B2	**Tel.No.** 604-356-6552
Department/Branch Fisheries & Oceans, Pacific Region	**FAX No.** 604-356-6390

Researchers

Humfrey Melling and W. Paul Budgell

Project Title **Beaufort Sea Ice Motion Programme**	**Status** **New** [ ] **Ongoing** [X] **Completed** [ ]

Objectives

To improve predictions of sea-ice movement through incorporation of more realistic ice-ocean dynamics into numerical models.

Methods

Lab [ ] **Field** [X] **Modelling** [X] **Others**

Findings

Three major observational programmes aimed at acquiring a regional descriptive oceanography, and data sets suitable for model evaluation, have been completed. A fourth programme, carried out in 1989, observed the momentum budget of ice and ocean over a 100 km scale, in conjunction with detailed visualization of momentum exchange phenomena at sites of heavily-ridged ice. Three regional numerical models have been developed for ice-drift and ocean-current simulation. These range in sophistication from a barotropic formulation, to a four-layer isopyenal-coordinate formulation.

Publications

Organization and Address	Tel.No.
Département de géne civil, 1913 Université Laval, Québec 10, Québec, G1K 7P4	418-656-2205
Department/Branch Laboratoire de mecanique de glace	**FAX No.** 418-656-2929

Researchers

Bernard Michel, E. Stander and P. Barrette

Project Title	Status	
Mechanisms of Crystal Alignment in Sea Ice	**New**	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

To study the effects of flow velocity and stresses on crystal alignment in sea ice.

Methods

Lab [X] **Field** [ ] **Modelling** [ ] **Others**

Findings

Flow velocity causes an important alignment. The effects of deformation are under study.

Publications

Stander, E. and B. Michel, 1988. Experimental study of the effects of current velocity on the development of aligned columnar sea ice. Comptes rendus, 56e congrès de l'Association canadienne française pour l'avancement des sciences, Colloque de Génie Nordique, Moncton, Nouveau-Brunswick, 10 pp.

Stander, E. and B. Michel, 1989. The development of aligned columnar sea ice: a field investigation. Journal of Glaciology, 33(120), 217-223

Stander, E. and B. Michel, 1989. The effect of fluid flow on the development of preferred orientations in sea ice: laboratory experiments. Cold Regions Science and Technology, 17(2), December, 153-161

Organization and Address Département de géne civil, 1913 Université Laval, Québec 10, Québec, G1K 7P4	**Tel.No.** 418-656-2205
Department/Branch Laboratoire de mecanique de glace	**FAX No.** 418-656-2929

Researchers

Bernard Michel, B. Doyon and P. Barrette

Project Title **Creep of Large Crystals**	**Status** **New** [X] **Ongoing** [ ] **Completed** [ ]

Objectives

Study of creep mechanisms in samples made of few crystals, specifically of delayed elastic effects.

Methods

Lab [X] **Field** [ ] **Modelling** [ ] **Others**

Findings

New project

Publications

Organization and Address	Tel.No.
Tecsult Inc., 85 rue Ste-Catherine Ouest, Montréal (Québec), H2X 3P4	514-287-8500
Department/Branch Geotechnical and Water Resources	**FAX No.** 514-287-8643

Researchers
Sylvester Petryk (Tecsult), R. Crason (Acres), G. Holder (LaSalle Hydraulic Laboratory) and P. Ko (Lavalin)

Project Title	Status	
Development of a Comprehensive Numerical River Ice Model	**New**	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives
To design, program, test and document a comprehensive numerical river ice model in collaboration with Environment Canada and other user agencies.

Methods
Lab [ ] **Field** [ ] **Modelling** [X] **Others**

Findings

To date the following phases of the project have been completed:
- design of the model
- identification and priority ranking of the modules
- design of the driver (simulator) and the inter-relationships between the modules
- design of the computation procedure for each module
- preparation of the programming instructions
- work progress on coding and debugging of the ice and hydraulics modules.

Publications

Petryk, S., R. Carson, D. Hodgins, F. Parkinson and S. Beltaos, 1990. Development of a comprehensive numerical river ice model. Cold Regions Monograph, American Society of Civil Engineers, August (in press)

Organization and Address	Tel.No.
Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2	902-426-3584
Department/Branch Fisheries & Oceans/Ocean Circulation	**FAX No.** 902-426-2256

Researchers

Simon Prinsenberg, Moto Ikeda and Ingrid Peterson

Project Title	Status	
Oceanographic Analysis of Sea Ice and Icebergs	**New**	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

1. Study the response of sea ice distribution on seasonal and longer time scales to atmospheric and oceanographic forcing.
2. Develop a hierarchy of numerical models to hindcast and ultimately predict sea ice distribution on the Candian East Coast.
3. Develop instrumentation and field program to aid in model development and verification.

Methods

Lab [ ] **Field** [X] **Modelling** [X] **Others** Satellite Imagery

Findings

1. Annual sea ice extent in the Western Labrador Sea (1963-1988)shovs strong spatial coherence. However, north-south differences are strongly related to north-south differences in atmospheric conditions.
2. Ice velocities obtained from satellite-tracked ice beacons and from satellite imagery are in good agreement and are highly correlated with geostrophic winds. They also reveal topographic steering of ocean currents around banks and saddles on the Labrador/Newfoundland shelf.

Publications

Peterson, I.K. and S.J. Prinsenberg, 1990. Sea ice fluctuations in the western Labrador Sea (1963-1988). Canadian Technical Report of Hydrography and Ocean Sciences No.123, 130 pp.

Prinsenberg, S.J. and I.K. Peterson, 1989. Ice drift. In - LIMEX '89 Data Report, Section 3.12, 13 pp.

Organization and Address National Hydrology Research Institute, 11, Innovation Blvd, Saskatoon, Saskatchevan, S7N 3H5	**Tel.No.** 306-975-5749
Department/Branch Hydrological Sciences Division	**FAX No.** 306-975-5143

Researchers

T.D. Prowse, S. Beltaos (NWRI) and B.C. Burrell (N.B.)

Project Title **Nashvaak River Break-Up**	**Status** **New** [ ] **Ongoing** [ ] **Completed** [X]

Objectives
Ascertain the rate, sequence and regularity of break-up, analyse meteorological and hydrometric conditions and integrate information.

Methods
Lab [ ] **Field** [X] **Modelling** [ ] **Others**

Findings A complete review of hydrometeorological conditions controlling break-up and ice jamming on the Naskvaak River, New Brunswick, was completed. A preliminary ice-jam analysis was conducted and a break-up forecast model tested. A summary report was compiled and presented at the Eastern Snow Conference. A more comprehensive NHRI report is in progress and a journal paper is in preparation.

Publications

Prowse, T.D., S. Beltaos, B.C. Burrell, P. Tang and J. Dublin, 1989. Breakup of the Nashvaak River, New Brunswick. Proceedings, 46th Annual Eastern Snow Conference, 7-9 June 1989, Québec, Quebec, **-** [CS-89037]

Prowse, T.D., 1989. 4. River ice monitoring/Surveillance de la glace fluviale. New Brunswick river ice manual/Guide des glaces fluviales au Nouveau-Brunswick, New Brunswick Subcommittee on River Ice/le Sous-comité responsable des glaces de cours d'eau du Nouveau-Brunswick, Inland Waters Directorate/Direction générale des eaux intérieures, Environment Canada/ Environnement Canada, New-Brunswick Department of the Environment/Ministère de l'environnement du Nouveau-Brunswick, Fredericton, New Brunswick, August/août, 7-10 [CS-88005]

Organization and Address	Tel.No.
National Hydrology Research Institute, 11, Innovation Blvd, Saskatoon, Saskatchevan, S7N 3H5	306-975-5749
Department/Branch Hydrological Sciences Division	**FAX No.** 306-975-5143

Researchers

T.D. Prowse, M.N. Demuth and H. Chev

Project Title	Status	
Mechanical Strength of 0°C River Ice	**New**	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

Develop field and laboratory to measure changes in the compliance of 0°C ice and integrate this with the radiation effects on the morphological structure.

Methods

Lab [X] **Field** [X] **Modelling** [X] **Others**

Findings

Field experiments of changes in ice strength were conducted on a local lake site during March - April, 1989, and on the Liard River in April, 1989. Publications deal with ice strength changes and a new system for measuring in-situ strength. For the first time measurements of in-situ strength were made during the radiation-decay 0°C period.

Publications

Beltaos, S., R. Gerard, S. Petryk and T.D. Prowse, 1990. Working Group on River Ice Jams: Field Studies and Research Needs. NHRI Science Report No.2, National Hydrology Research Institute, Saskatoon, Saskatchevan, 121 pp.

Demuth, M.N. and T.D. Prowse, 1988. In situ testing of river-ice strength using a hydraulic borehole jack. Proceedings of the 45th Annual Eastern Snow Conference, 8-9 June 1988, Lake Placid, New York, 181-185 [CS-88051]

Prowse, T.D., M.N. Demuth and C.R. Onclin, 1988. Using the borehole jack to determine changes in river ice strength. Proceedings, 5th Workshop on Hydraulics of River Ice/Ice Jams, 21-24 June 1988, Winnipeg, Manitoba, 283-303 [CS-88043]

Organization and Address Center for Res. in Experimental Space Science, York Univ., 4700 Keele Street, Toronto, Ontario, M3J 1P3	**Tel.No.**
Department/Branch Ice Research & Development, AES	**FAX No.**

Researchers

Rene O. Ramseier

Project Title **Microvave Remote Sensing of Floating Ice, Oceans and Atmosphere**	**Status** **Nev** [ ] **Ongoing** [X] **Completed** [ ]

Objectives

Methods
Lab [ ] **Field** [ ] **Modelling** [ ] **Others**

Findings

Publications

Organization and Address Inland Waters Directorate, Environment Canada, Ottawa, Ontario, K1A OH3	Tel.No. 819-953-1526
Department/Branch Water Planning & Management Branch	FAX No. 819-997-8701

Researchers

River Ice Committee (Federal/Provincial)

Project Title	Status
River Ice Model Development	New [X] Ongoing [ ] Completed [ ]

Objectives

To develop a generalized, non-proprietary dynamic river ice model

Methods

Lab [ ] Field [ ] Modelling [X] Others

Findings

See report by Petryk

Publications

Organization and Address Canpolar Inc., 265 Rimrock Road, Unit 4, Toronto,Ontario, M3J 3C6	Tel.No. 416-635-5484
Department/Branch	FAX No. 416-635-5353

Researchers

J. Rossiter, L. Lalumiere; Aerodat Limited

Project Title	Status	
Development of Airborne Sea Ice Thickness Sensor	New	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

To develop an operational device for reliable measurement of sea ice thickness from a helicopter.

Methods

Lab [ ] **Field** [X] **Modelling** [X] **Others** Engineering development

Findings

Electromagnetic (EM) induction has been shown to be capable of measuring the thickness of a wide variety of sea-ice types from an altitude of about 50 m. Current work is aimed at: automatic, real-time data interpretation; determination of ice conductivity; development of a lightweight operational system.

Publications

LIMEX report

Holladay, J.S., J.R. Rossiter and A. Kovacs, 1990. Airborne measurement of sea ice thickness using electromagnetic induction. Proceedings, 9th International Conference on Offshore Mechanics and Arctic Engineering (OMAE), 18-23 February 1990, Houston, Texas, (8 pp.)

Rossiter, J.R., J.S. Holladay and L.A. Lalumiere, 1990. Validation of airborne sea ice thickness measurement using electromagnetic induction during LIMEX '89. Contract report submitted to Bedford Institute of Oceanography, Dartmouth, Nova Scotia, March, 90 pp.

Organization and Address Science Institute of the NWT, Box 1617 Yellowknife, NWT X1A 2P2	**Tel.No.** 403-873-7592
Department/Branch Scientific Services	**FAX No.** 403-873-0227

Researchers

David Sherstone

Project Title **River Ice Growth and Decay:** **Mackenzie Delta and Bay River**	**Status** **New** [ ] **Ongoing** [X] **Completed** [ ]

Objectives Determination of timing of maximum ice growth and rate of decay prior to mechanical break-up of ice by spring flood

Methods
Lab [ ] **Field** [X] **Modelling** [ ] **Others**

Findings Maximum thickness recorded later than reported in earlier research reports. Ice can be increasing in thickness immediately prior to break-up if air temperatures remain cold and snow cover persists on ice. These conditions lead to maximum ice jamming.

Publications

None since 1988.

Organization and Address	Tel.No.
WMS Associates Ltd., P.O. Box 1116, 458 York Street, Fredericton, New Brunswick, E3B 5C2	506-457-3200
Department/Branch Hydrotechnical Section	**FAX No.** 506-458-8461

Researchers

G.G. Snyder

Project Title	Status
Ice Forces on Structures	New [ ] Ongoing [ ] Completed [X]

Objectives

Investigate mechanisms of ice forces on structures with emphasis on bridge superstructures.

Methods

Lab [ ] **Field** [ ] **Modelling** [X] **Others** Literature review

Findings

- examination and summary of methodologies currently used to determine ice forces against structures.
- ice forces on bridge superstructures due to jamming against lower chord can be significant and lead to bridge failure. Methods of determing these forces were examined.
- current design code recommendations were also examined.

Publications

Organization and Address Department of Geography, University of Alberta, Edmonton, Alberta, T6G 2H4	**Tel.No.** 403-492-0352
Department/Branch Department of Geography	**FAX No.** 403-492-7219

Researchers

K. Szilder and E.P. Lozowski

Project Title **A Time-Dependent Thermodynamic Model of the Build-Up of Sea-Ice Platforms**	**Status** **New** [ ] **Ongoing** [X] **Completed** [ ]

Objectives

To develop a thermodynamic model simulating the growth of ice platforms as a function of meterological parameters and construction method.

Methods

Lab [X] **Field** [ ] **Modelling** [X] **Others**

Findings

Experience with the model suggests several possible methods for increasing the rate of ice growth under particular atmospheric conditions.

Publications

Lozowski, E.P., R.B. Charlton, C. Nguyen and K. Szilder, 1989. Some aspects of the interannual variability and persistence of global atmospheric and oceanic surface temperatures. Climatological Bulletin, 23(2), 60-66

Szilder, K., G. Henry, E.P. Lozowski and L. Labine, 1989. A simple numerical model for simulatying the climate and energy balance of the arctic tundra in summer. Proceedings, 2nd International Symposium on Cold Regions Heat Transfer, Sapporo, Japan,

Szilder, K. and E.P. Lozowski, 1989. Optimizing the growth thermodynamics of artificial floating ice platforms. Ocean Engineering, 16(1), 99-115

Szilder, K. and E.P. Lozowski, 1989. A time-dependent thermodynamic model of the build-up of sea-ice platforms. Journal of Glaciology, 33(120), 169-178

Szilder, K., E.P. Lozowski and T.W. Forest, 1990. A numerical model of sea water fusion process. Proceedings, 5th International Conference on Atmospheric Icing of Structures, Tokyo, Japan,

Szilder, K., E.P. Lozowski and T.W. Forest, 1990. Some applications of a numerical model of floating sea ice platforms. Proceedings, 9th International Conference on Offshore Mechanics and Arctic Engineering, Houston, Texas,

Organization and Address National Hydrology Research Institute, 11, Innovation Blvd, Saskatoon, Saskatchewan, S7N 3H5	**Tel.No.** 306-975-5749
Department/Branch Hydrological Sciences Division	**FAX No.** 306-975-5143

Researchers

G. Tsang

Project Title **Laboratory Investigation of Frazil and Anchor Ice**	**Status** **New** [ ] **Ongoing** [X] **Completed** [ ]

Objectives

Equipment construction, set up and background experiments.

Methods
Lab [X] **Field** [ ] **Modelling** [X] **Others**

Findings

Experimental equipment for an open-water experiment was designed, contracted and/or procured and steps taken to obtain a data acquisition system. A background experiment on the open water profile was obtained. The first year progress report was written and submitted to the sponsors.

Publications

Tsang, G., 1989. Laboratory investigation of frazil evolution, flocculation and the formation of anchor ice: Progress Report No.1 to Ontario Hydro, Manitoba Hydro and the New York Power Authority. NHRI Contribution No.89070, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, ** pp.

Tsang, G., 1990. Preliminary findings on formation and evolution of frazil and anchor-ice under laboratory conditions. Proceedings, Northern Hydrology Symposium, T.D. Prowse and C.S.L. Ommanney (Editors), 10-12 July 1990, Saskatoon, Saskatchewan, **-** [CS-90011]

Organization and Address	Tel.No.
Alberta Research Council, P.O. Box 8330, Postal Station F, Edmonton, Alberta, T6H 5X2	403-450-5276
Department/Branch Environmental Res. & Engineering	**FAX No.** 403-461-2651

Researchers

G. Van Der Vinne and D. Andres

Project Title	Status	
Regional Ice Forces in Alberta	**New**	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

The quantification of the break-up process and characterization of ice forces developed during break-up on a regional/climatic basis.

Methods

Lab [ ] **Field** [X] **Modelling** [ ] **Others**

Findings

Publications

Annual reports are produced

Organization and Address Alberta Research Council, P.O. Box 8330, Postal Station F, Edmonton, Alberta, T6H 5X2	**Tel.No.** 403-450-5276
Department/Branch Environmental Res. & Engineering	**FAX No.** 403-461-2651

Researchers

G. van der Vinne, D. Andres and T.D. Prowse (NHRI)

Project Title **Economic Impact of River Ice Jams in Canada**	**Status** **New** [ ] **Ongoing** [ ] **Completed** [X]

Objectives

To collect and categorize data on the cost of damage resulting from river ice jams across Canada.

Methods

Lab [ ] **Field** [ ] **Modelling** [ ] **Others** Survey

Findings

The total cost of ice jam damage is at least $766 million and possibly as great as $1.3 billion while the average annual cost over the last ten years was $22 million. Most damage occurred in Ontario, New Brunswick and Quebec and flood plain damage much more extensive than damage to river structures.

Publications

van der Vinne, G., 1989. Evaluation of the economic impact of river ice jams in Canada". Joint Alberta Research Council, National Hydrology Research Institute report No. SWE 98/05, April,

van der Vinne, G., D. Andres and T.D. Prowse, 1990. Economic impact of river ice jams in Canada. Proceedings, Northern Hydrology Symposium, T.D. Prowse and C.S.L. Ommanney (Editors), 10-12 July 1990, Saskatoon, Saskatchewan, **-** [CS-90012]

Organization and Address	Tel.No.
Department of Mechanical Engineering, The University of Calgary, Calgary, Alberta, T2N 1N4	403-220-7187
Department/Branch Mechanical Engineering	**FAX No.** 403-282-8406

Researchers

O.G. Vinogradov, A. Springer and P. Wierzba

Project Title	Status	
Computer Simulation of Flow of Broken Ice in Rivers	New	[X]
	Ongoing	[ ]
	Completed	[ ]

Objectives

To simulate the ice jam and ice cover break-up in rivers.

Methods

Lab [ ] **Field** [ ] **Modelling** [X] **Others**

Findings

A computer code is written which allows simulation of the flow of broken ice as a multi-body dynamic problem for an arbitrary river geometry, random distribution of ice floes on the water surface and random floe sizes. A computer run permits determination of the rate of floe accumulation near the obstructions and the corresponding ice forces.

Publications

Vinogradov, O.G., A. Springer and P. Wierzba, 1990. On computer simulation of ice motion in rivers. Proceedings, Northern Hydrology Symposium, T.D. Prowse and C.S.L. Ommanney (Editors), 10-12 July 1990, Saskatoon, Saskatchewan, NHRI Symposium No.*, National Hydrology Research Institute, Saskatoon, Saskatchewan, **-**

Organization and Address	**Tel.No.**
Institute of Ocean Sciences, Box 6000, 9860 West Saanich Road, Sidney, B.C., V8L 4B2	604-356-6587
Department/Branch Fisheries & Oceans, Pacific Region	**FAX No.** 604-356-6390

Researchers

Yunbo Xie (UBC graduate student) and David M. Farmer

Project Title	**Status**	
Acoustic Study of Sea Ice Through Ice Cracking Sound	**New**	[ ]
	Ongoing	[X]
	Completed	[ ]

Objectives

Understanding the relationship between the acoustic features of the ice cracking sound, the mechanical properties of the ice cover and the stress-generation mechanisms through environmental forcing.

Methods

Lab [ ] **Field** [X] **Modelling** [ ] **Others**

Findings

1. The ice cracking sound has a dipole radiation pattern, i.e., source directivity $\propto \cos\theta$.
2. Ice cracking sound is a relatively narrov band signal and angularly dispersive, i.e., dominant frequency (F) changes with θ. $F \propto (1/\sin\theta)$
3. There is a potential that Young's modulus and ice thickness can be inferred from the observed cracking signals, i.e., $EH \propto F^2 \sin^4\theta$

Publications

Farmer, D.M. and Y. Xie, 1989. The sound generated by propagating cracks in sea ice. Journal of the Acoustical Society of America, 85(4), 1489-1500

Xie, Y. and D.M. Farmer, 1990. Acoustic radiation patterns from thermally stressed sea ice. Submitted to Journal of the Acoustical Society of America